The Integration Of Analysis And Test For Full Vehicle Structural Durability

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Abstract	
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Who & What is Deere?

- **De-Centralized Company evolving to global manufacturing of products.**
- **Mid-sized company - $13B.**
- **Improved communication & time compression forcing change in processes. Collaboration not an option - rather a requirement.**
- **Most of products are specialized vehicles operated in a range of off-road conditions at high-power levels for long periods of time.**
- **Mature products with customer expectations of high durability and availability**

The Challenge - Global Sharing of Technology & Techniques

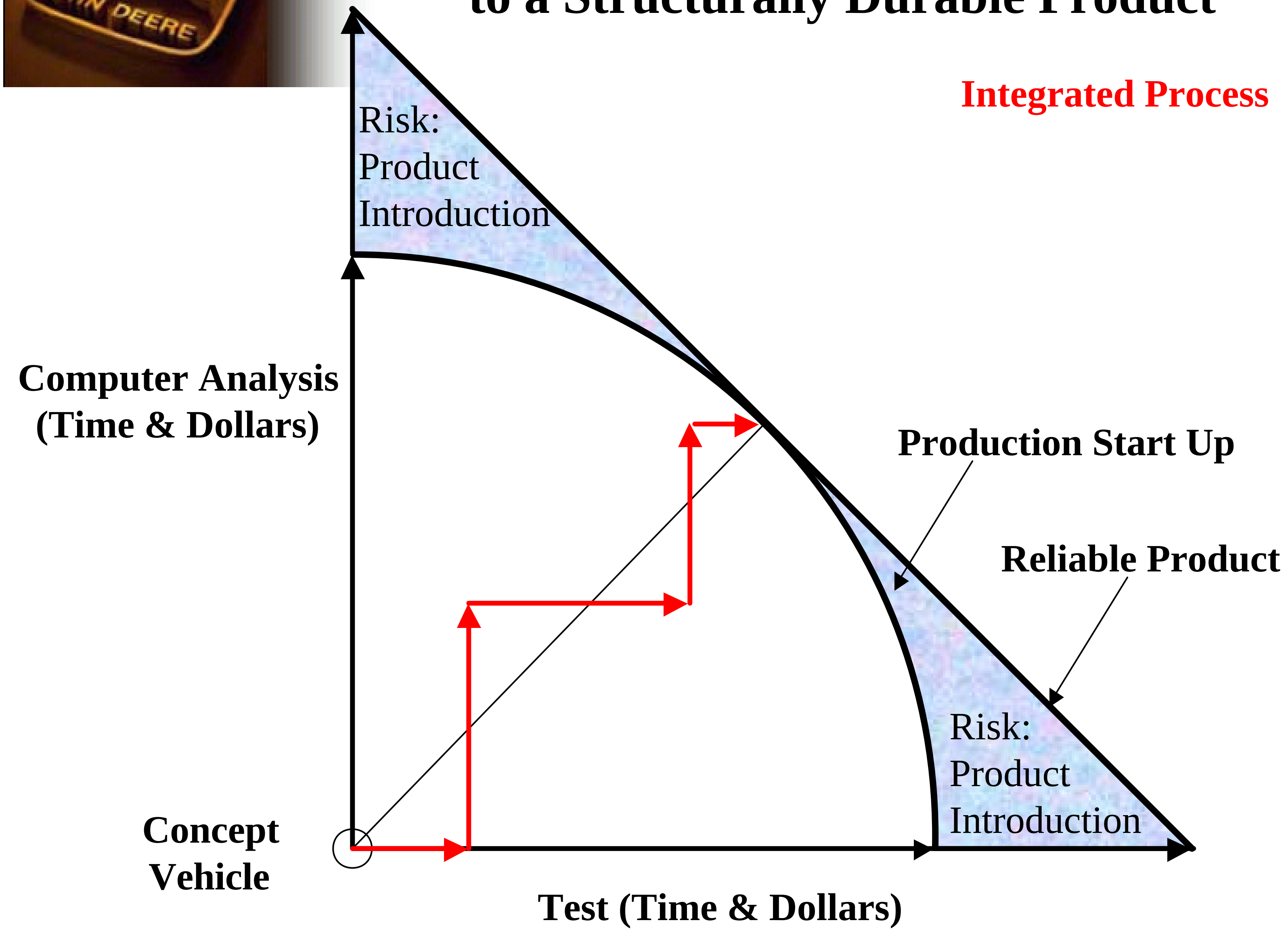
- Design Anywhere - Manufacture Anywhere
- About 40 Engineering Locations - Depending on Definition of Product Engineering
- Diverse Products - Tractors, Combines, Forage Harvesters, Log Skidders, Dozers, Backhoes, Road Graders, Balers, Lawn & Garden Tractors, Mowers, Chain Saws, Etc.
- Increased Competition
- Faster Pace => More simulation & analysis.

Structural Durability Development Through Integration Of Analysis And Full Vehicle Test

What & Why:

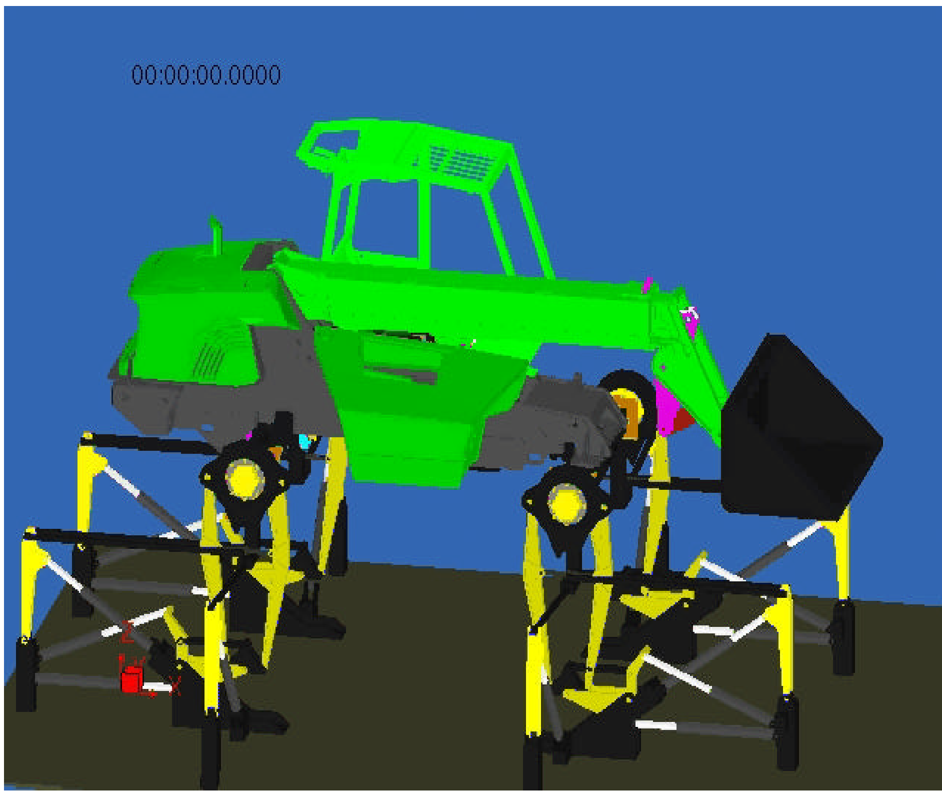
- Correlate Fatigue/Finite Element/Dynamic Analysis to the Lab (Field) Test
- “Field Test” the Structural Design in the Computer Before Building the Hardware
- Establish Confidence in Fatigue Predictions By Comparing to Actual Test Fatigue Lives
- Define Subsystem Load Information from the Dynamic Model/Lab Test Load Histories
- Obtain Fatigue Life Contours for Multiple Load Inputs for the Composite Duty Cycle

Optimal Computer Analysis/Test Path to a Structurally Durable Product

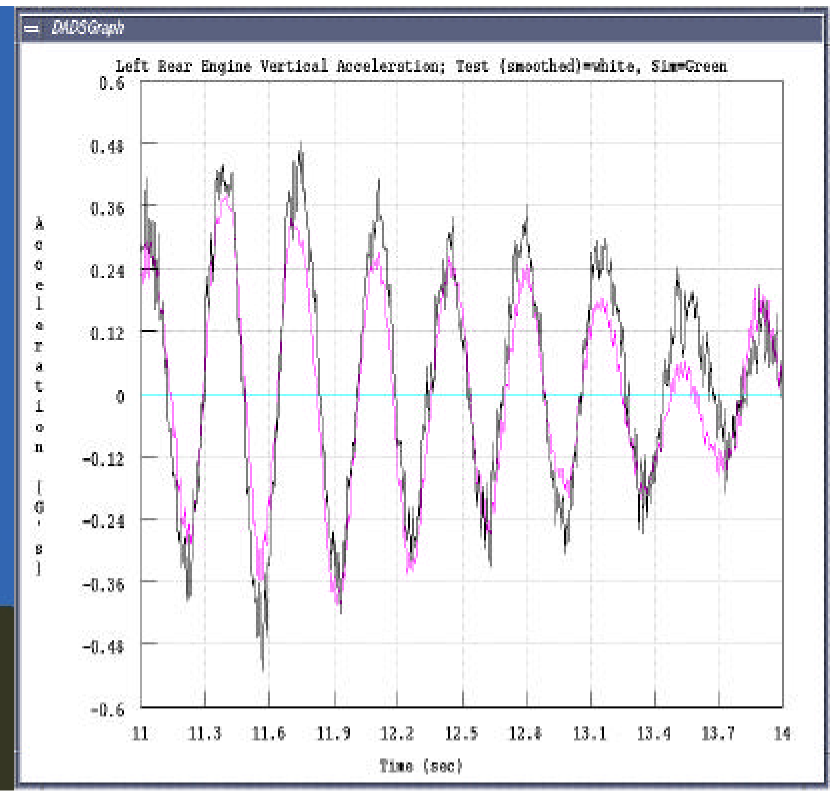


Dynamic Model of Telehandler and Correlation with the Lab Test

Dynamic Model
Rough Transport Empty

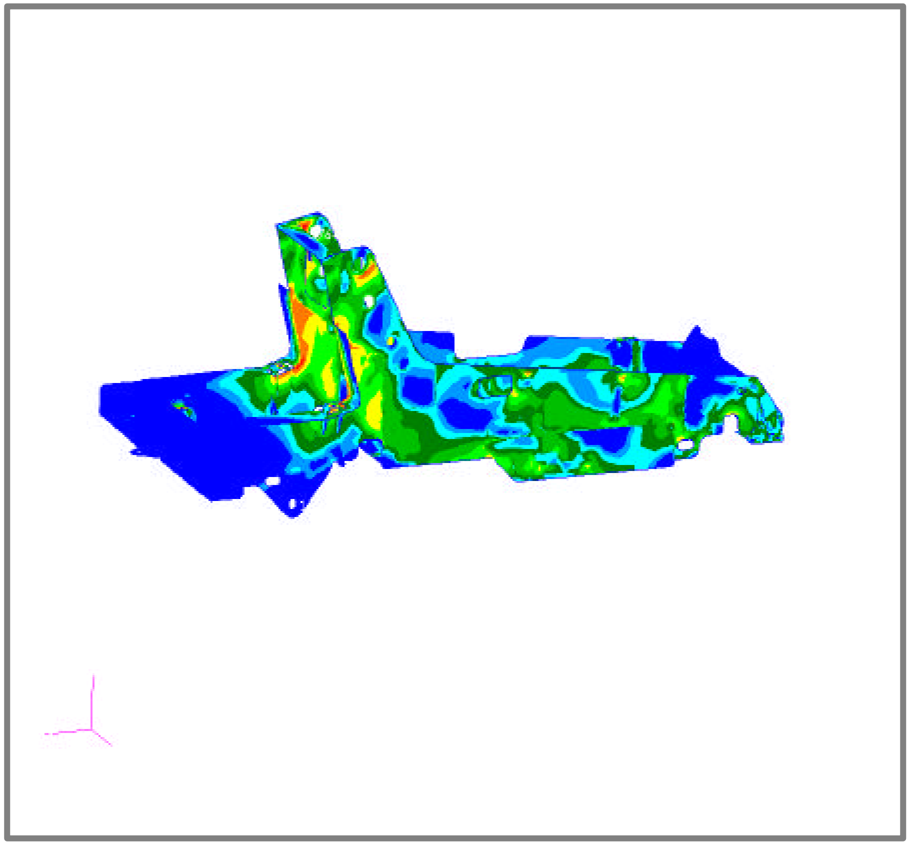


Left Rear Engine Vertical Acceleration Correlation between Dynamic Model and Lab test

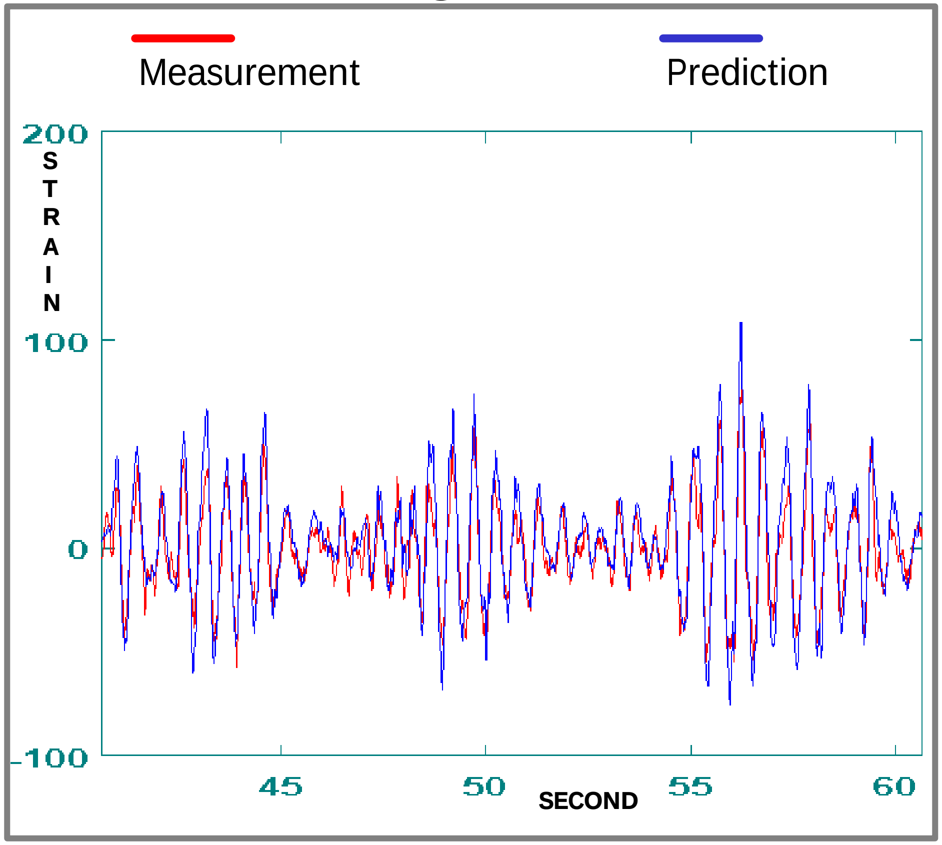


Finite Element Model of Telehandler Chassis and Correlation with Strain Gage Measurement from a Lab Test

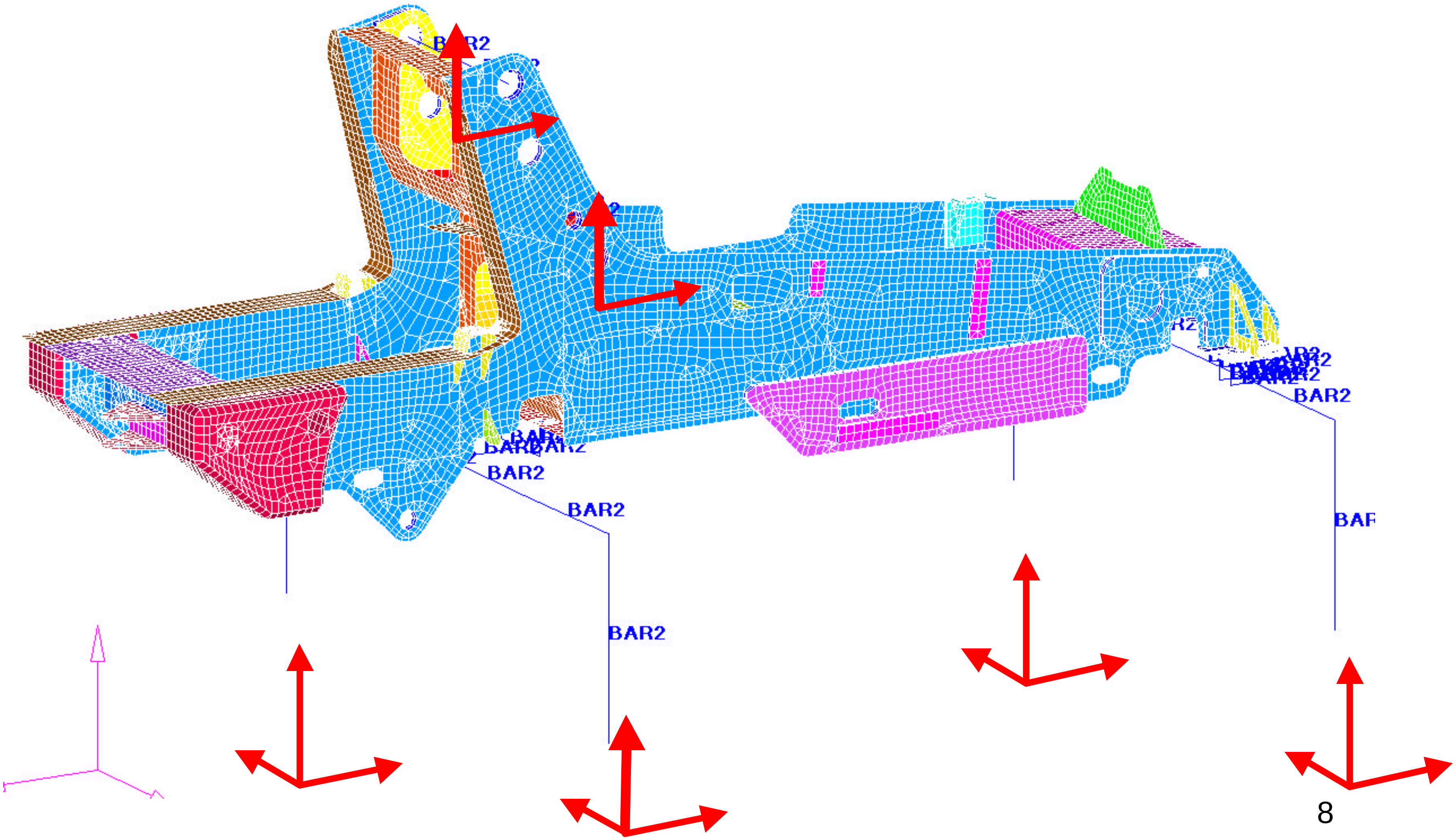
Strain Contour of the Finite Element Model



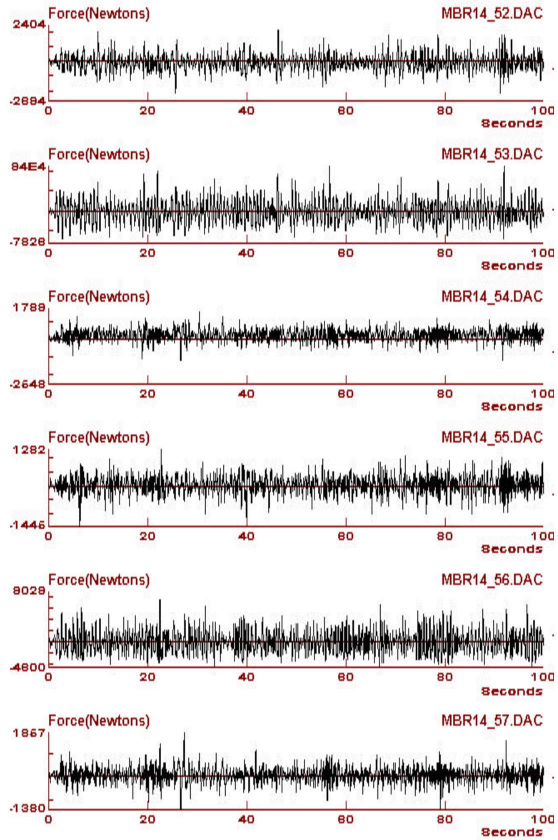
Strain Correlation between Finite Element/Fatigue Model and Lab test

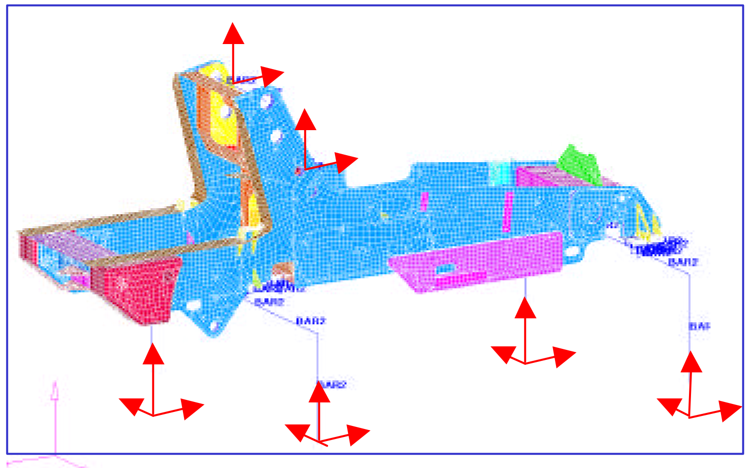


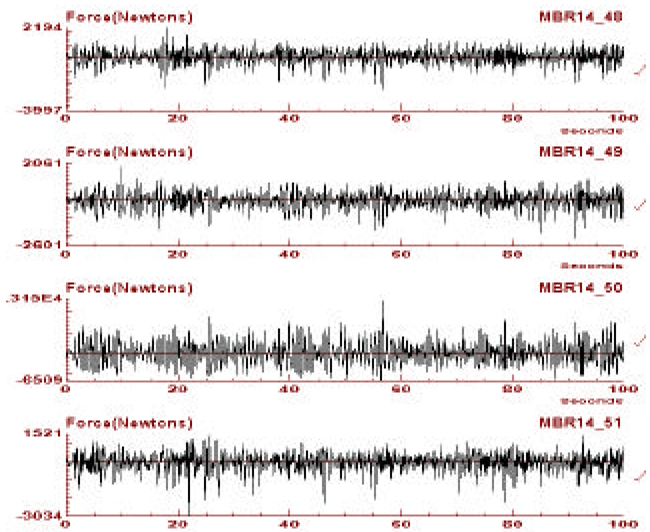
Finite Element Model of Telehandler Chassis and Multiple Load Inputs

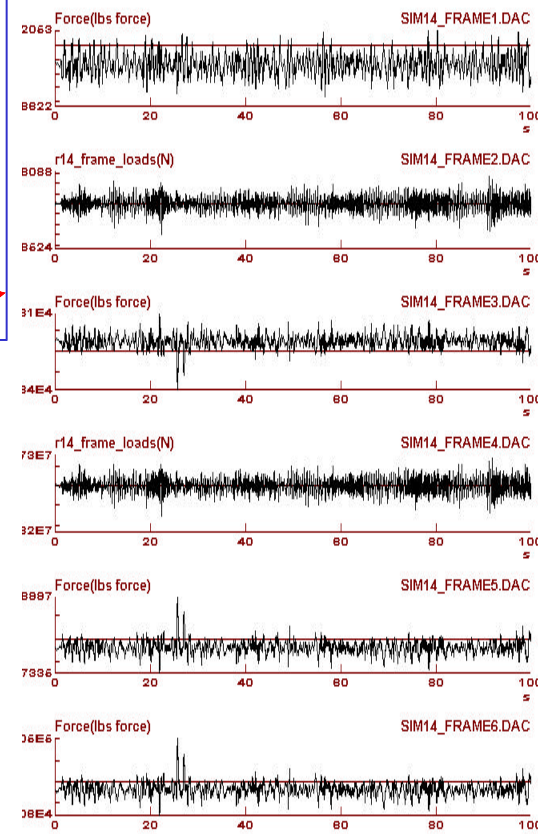


Time Histories Associated with the Multiple Load Inputs

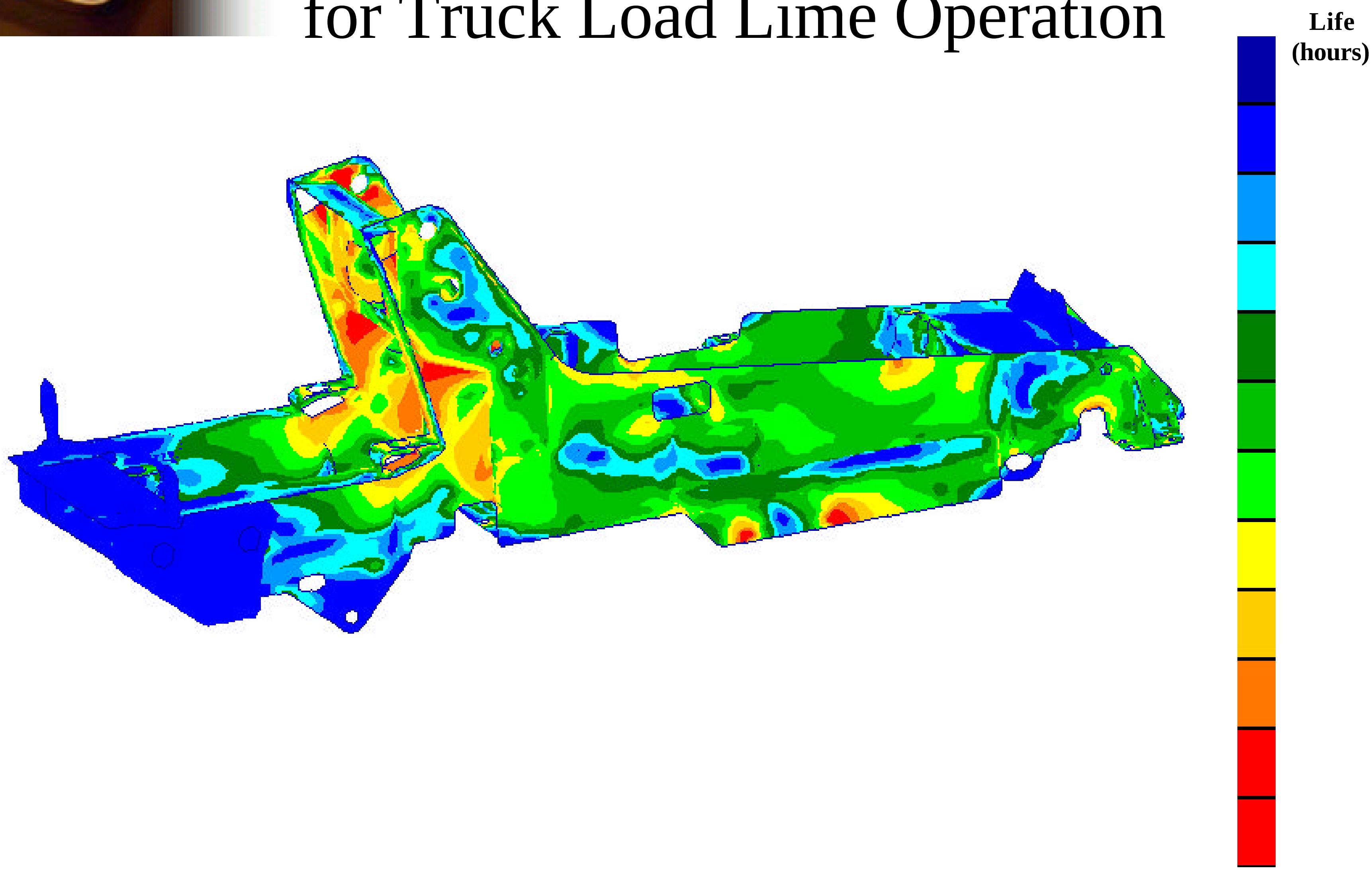








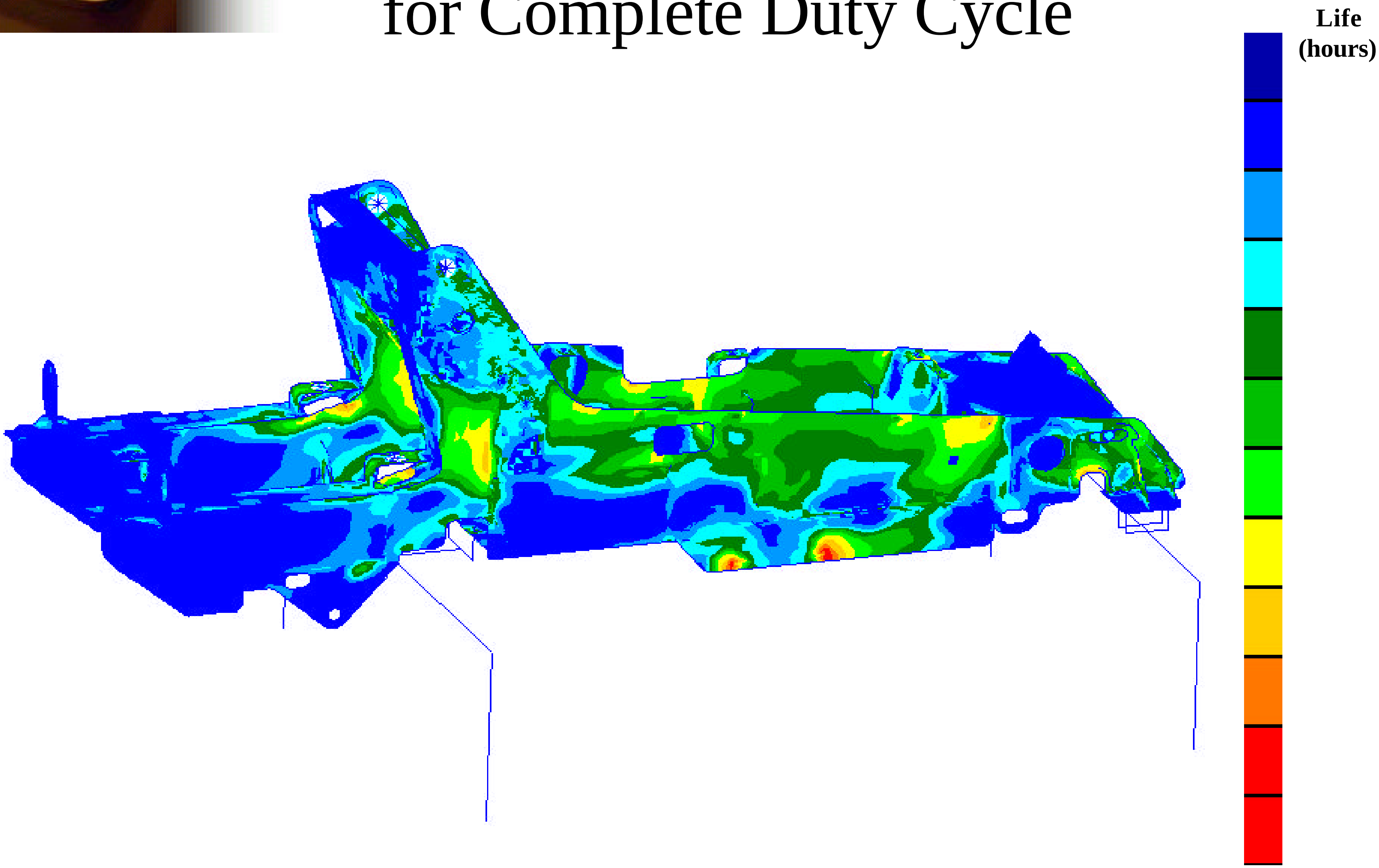
Fatigue Life Contours of Chassis for Truck Load Lime Operation



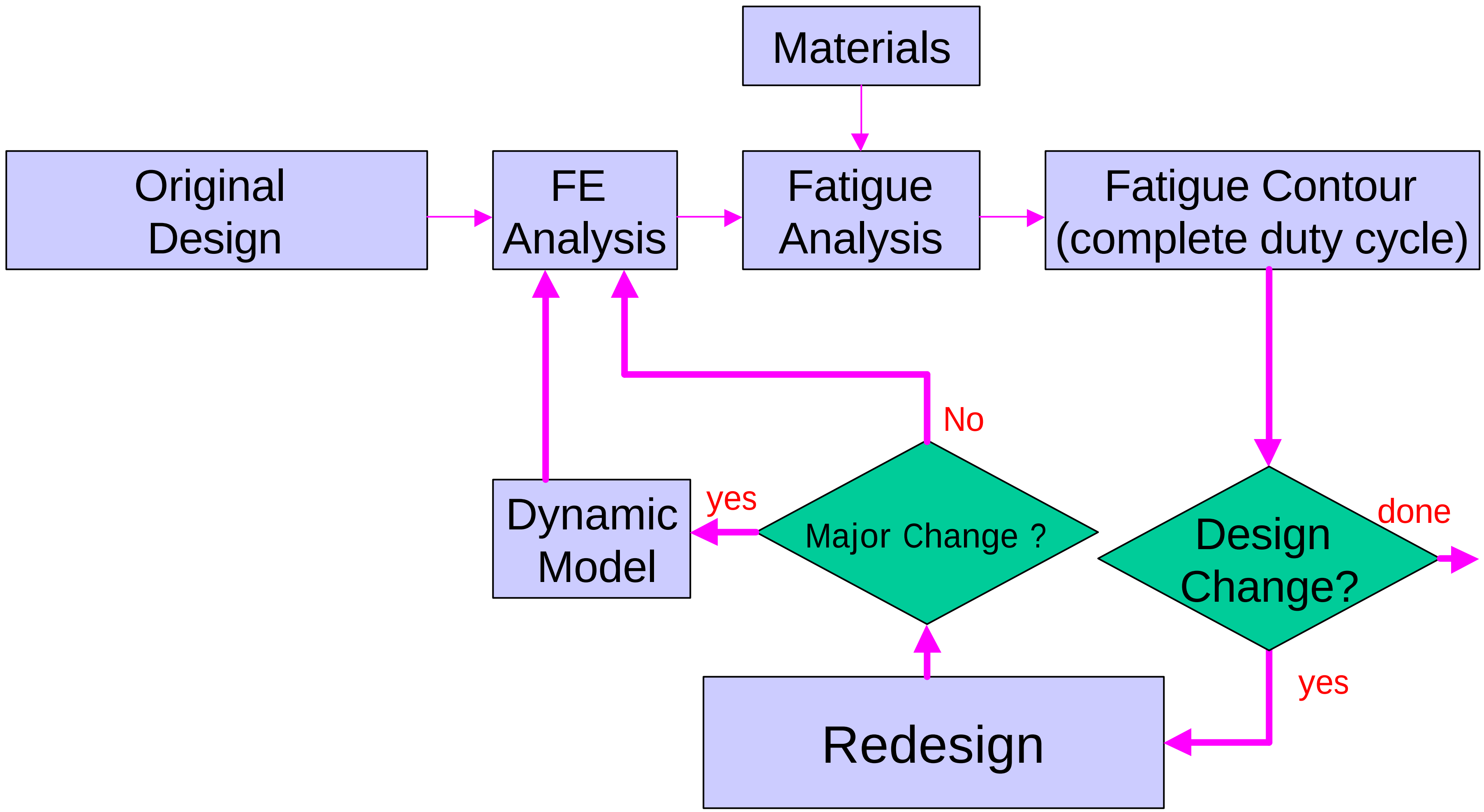
Lab Rig Operations - Need Percentages of Test Time

• Normal Transport Loaded	xx%
• Figure 8's Empty	xx%
• Push Up Silage and Compact	xx%
• Truck Load Lime	xx%
• Muck Out Pit	xx%
• Truck Load Gravel	xx%
• ...	xx%
• ...	xx%
• ...	xx%

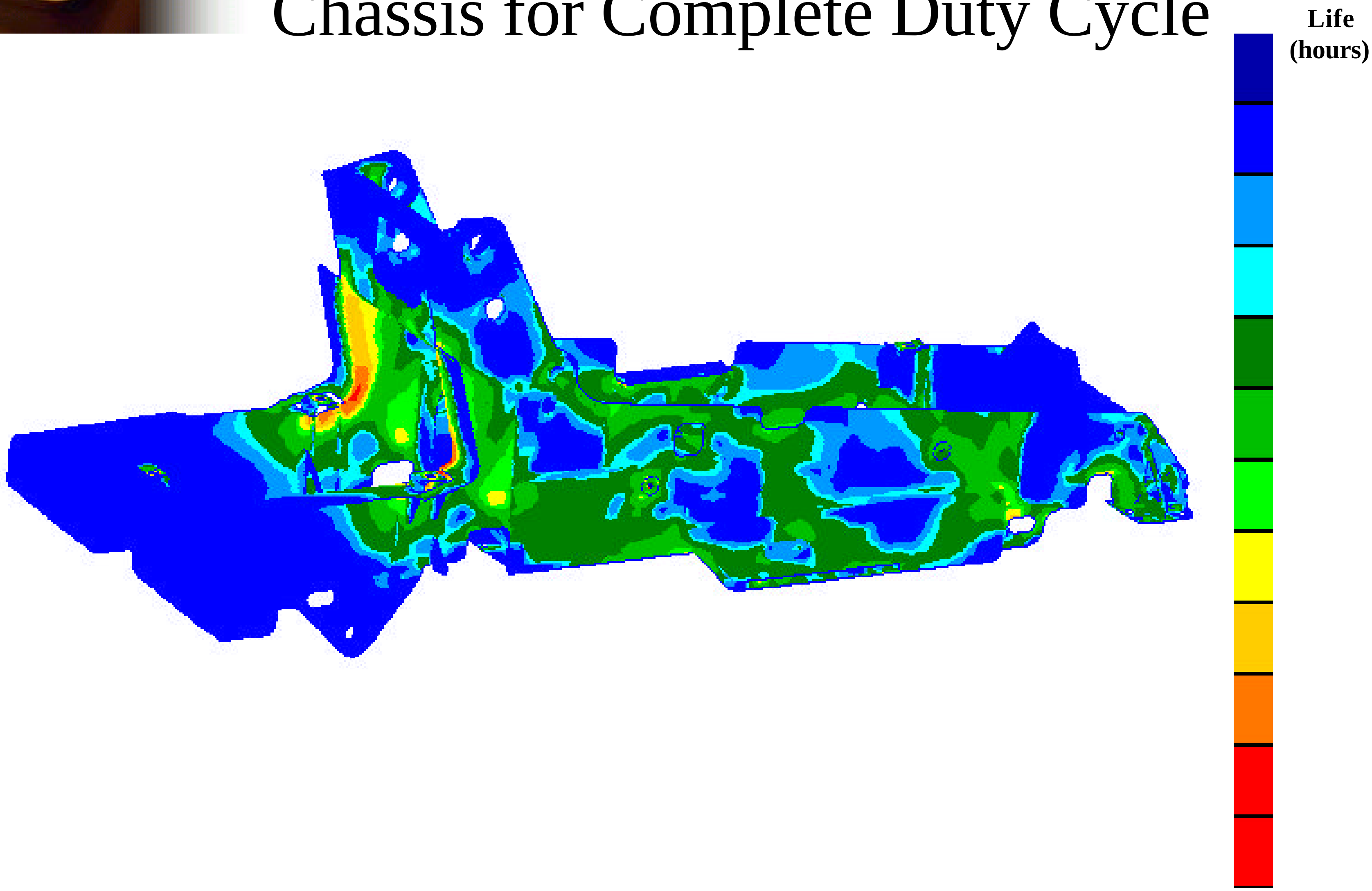
Fatigue Life Contours of Chassis for Complete Duty Cycle



Structural Design Iteration Process

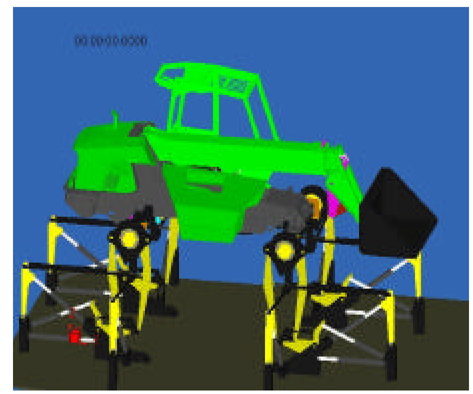


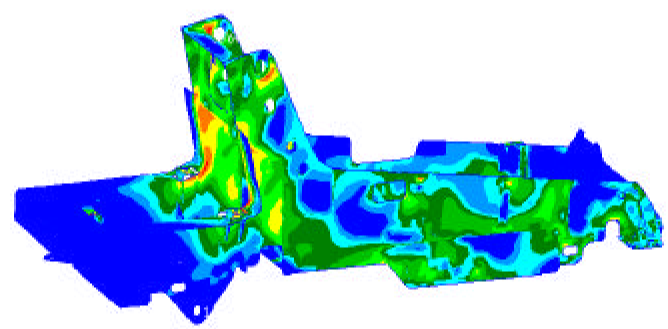
Fatigue Life of Second Re-Designed Chassis for Complete Duty Cycle



From Competitor Evaluation to Final Build

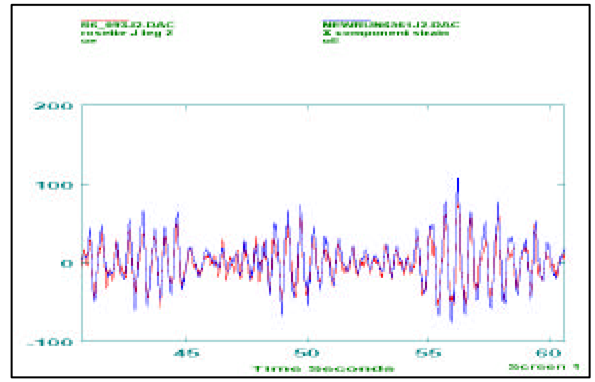
- **Competitor Evaluation**
  - Field Data Acquisition
  - Lab Test
  - Dynamic Model - Validate
  - Finite Element & Fatigue Analysis - Validate
- **Current Production**
  - Field Data acquisition
  - Lab Test
  - Dynamic Model - Validate
  - Finite Element & Fatigue Analysis - Validate
- **Initial Design**
  - Dynamic Model
  - Finite Element & Fatigue Analysis
  - Prototype Build (for durability evaluation)
- **Design Iterations**
  - Finite Element & Fatigue Analysis
- **Final Design**
  - Lab Test (validation - 3rd production vehicle)





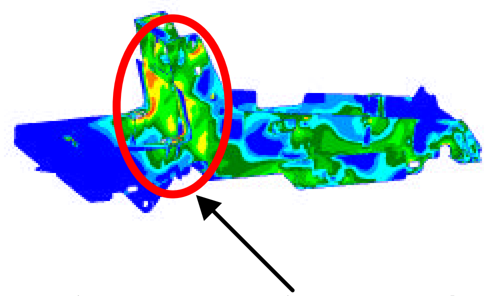
Analysis Highlights

- **Confidence in the Process**
  Excellent correlation between measured (Lab Test) and predicted (Dynamic-FEA-Fatigue) strains.



- **Analysis before Prototype Build**
  Fatigue analysis of initial Deere design highlighted problem areas, enabling re-design before first prototype build.

- **Development of Analysis Process**
  - Dynamic Model - DADS
  - Finite Element Model - Hypermesh
  - Finite Element Analysis - Abaqus (unit load cases)
  - Fatigue Analysis - MSC/Fatigue



Primary Re-Design Focus Area

- **Enhancement of Analysis Process**
  - Frame : 3 major designs iterations in 6 months
  - Inner Boom : 6 major design iterations in 2 months
  - Outer Boom : 2 major design iterations in 1 month

Lessons Learned

- It's not easy!
- Requires experienced personnel.
- Both test and analysis have equal weight and value in the design iteration effort.
- Acceptance is comparable to any new technology - requires proof and then becomes part of the routine process.

Conclusions

- Full Vehicle Structural Durability Behavior Is Predictable
- Prediction of Full Vehicle Structural Durability Behavior Is Fast Enough to Be Practical
- Prediction of Full Vehicle Structural Durability Behavior Is Cost-Effective
- The Durability of a Structure Can Be Optimized Using Computer Models Before Production